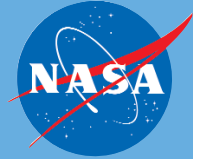


NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

WEATHER PROGRAMS

The National Aeronautics and Space Administration (NASA) Headquarters Weather Support Office has continued to improve NASA's weather support capabilities for both manned and unmanned space launch vehicles. It is expected that these improvements will strengthen and enhance the information provided to the ground-based decision makers and astronaut observers to insure that NASA achieves the best operational posture for Space Shuttle launches and landings. The goal of the operations program is to provide the specialized meteorological data needed by operational forecasters at the Kennedy Space Center (KSC) and Johnson Space Center (JSC). NASA also maintains a sophisticated fleet of eighteen Earth-monitoring satellites, measuring a vast number of Earth properties. The focus of Earth Science Research is to integrate satellite observations, numerical model and theoretical studies of various Earth system attributes. These attributes include ocean currents, temperature and biological activity; atmospheric ozone and aerosols; tropical rainfall, lightning; atmospheric temperature and humidity structure; Antarctic and Arctic sea ice; volcanic emissions and gravitational anomalies in the Earth's crust. NASA also performs aviation research to improve safety, develop weather information technologies, and increase aviation system capacity. Advanced operations technologies can increase the number of operations per runway in all weather conditions. The research applies to both commercial and general aviation.



APPLIED METEOROLOGY UNIT - RESEARCH & OPERATIONS

The goal of the National Aeronautics and Space Administration (NASA) weather operations program is to provide specialized meteorological data and techniques needed by Air Force forecasters at Cape Canaveral Air Force Station (CCAFS), adjacent to Kennedy Space Center (KSC), and by the National Weather Service's (NWS) Spaceflight Meteorology Group (SMG) at Johnson Space Center (JSC), to support NASA's Space Shuttle and Expendable Launch Vehicle (ELV) programs. Their greatest challenge is to accurately measure and forecast the mesoscale weather events that strongly impact ground processing, launch, and landing operations.

To successfully support the diverse, unique and complex requirements of their many customers' 24/7 operations, in the mesoscale driven lightning capital of America, requires:

1. A sophisticated weather infrastructure which includes many systems normally found only in research field programs rather than operations;
2. A dedicated capability to transition research and technology to support new or poorly satisfied operational requirements;

3. Rigorous training to ensure the weather infrastructure, diverse customer requirements, and dynamic, mesoscale weather are thoroughly understood; and

4. At least 2-3 years on-site experience to adequately master the infrastructure, the weather, and the requirements sufficiently to provide timely, tailored, accurate support to the many weather sensitive daily operations.

The focal point for satisfying Requirement 3 above and assisting with Requirements 1 and 2 is the Applied Meteorology Unit (AMU). The AMU, co-located with the Air Force's Range Weather Operations at CCAFS, provides a facility to develop, evaluate and, if warranted, transition new meteorological technology into operations. For instance, the AMU strives to develop techniques and systems to help predict and avoid the impacts of Central Florida's frequent thunderstorms which endanger the ground processing, launch, and landing operations of the American Space Program-Space Shuttle, DOD, and commercial organizations. The AMU has focused special attention on evaluating and transitioning mesoscale numerical models, and developing

forecast techniques applicable to Central Florida. The AMU functions under a joint NASA, Air Force, and NWS Memorandum of Understanding.

The AMU is developing statistical lightning forecast equations that will provide a lightning occurrence probability for the day by 0700 Local Time during the months May - September. The tool will be based on results from several research projects. If tests of



the equations show they improve the daily lightning forecast, the AMU will develop a PC-based tool from which forecasters can display the daily probabilities.

Three of the data types used to develop the technique are:

- Cloud-to-Ground Lightning Surveillance System data,
- 1200 UTC sounding data from synoptic sites in Florida, and
- 1000 UTC CCAFS upper air sounding data.

The goal is to develop a set of statistical equations to forecast the probability of lightning occurrence for the day. This will aid forecasters in evaluating flight rules and determining the probability of launch commit criteria violations, as well as preparing forecasts for ground operations.

The AMU is developing a model to forecast the probability at least three Shuttle ascent imaging cameras can view the Shuttle Launch Vehicle (LV) unobstructed by cloud at any time from launch to Solid Rocket Booster (SRB) separation.

Optical imaging of the Shuttle LV from ground-based and airborne cameras is susceptible to obstruction by clouds. The Columbia Accident Investigation Board (CAIB) recommended the Shuttle ascent imaging network be upgraded to have the capability of providing at least three useful views of the LV from lift-off to SRB separation. In response, the NASA/KSC Weather Office tasked the AMU to develop a model to forecast the probability cloud will not obstruct the view of at least "X" imaging cameras at any time from launch to SRB separation. An analysis of the sensitivity of viewing probabilities to upgrades of the camera network was developed in collaboration with the Shuttle Launch Director, the KSC Intercenter Photo Working Group, and the 45th Weather Squadron (45WS) Shuttle Launch Weather Officer.

A 3-D computer model was random-

ly seeded with cloud fields and viewing probabilities were computed for selected cloud scenarios. The AMU model was based on computer simulations of

- 1) idealized, random cloud coverage scenarios;
- 2) the optical lines-of-sight from cameras to the LV using the camera network before and after upgrades for Return to Flight (RTF); and
- 3) a LV ascent trajectory for a launch from Pad 39B to the International Space Station (ISS). Based on the results, launch day criteria and launch decision strategies are being developed and coordinated with senior Shuttle management.

The peak winds near the surface are an important forecast element for both the Space Shuttle and ELV programs. As defined in the Launch Commit Criteria (LCC) and the Shuttle Flight Rules (FRs), each vehicle has certain peak wind thresholds that cannot be exceeded in order to ensure vehicle safety during launch and landing operations. 45WS and the SMG indicate that peak winds are a challenging parameter to forecast. In Phase I of this task, climatologies and distributions of the 5-minute average and peak winds were created for the towers used in evaluating LCC and FRs. However, SMG uses a 10-minute peak as the standard for determining and verifying wind speed FRs. The AMU re-calculated the distributions and resulting probabilities of exceeding peak-wind thresholds using a 10- instead of 5-minute peak for the Shuttle Landing Facility (SLF) towers for all months. The AMU developed tool can be used on a personal computer to display the desired information quickly and easily.

The transparency of anvil clouds (high level ice clouds that spread away from the tops of a thunderstorm) is an important element in forecasting triggered lightning launch commit criteria. Opaque anvils can carry an electrical charge. If a vehicle flies through such

a charge, it could trigger lightning and be destroyed. The AMU identified 45 days during summer 2003, with thunderstorm anvil cirrus clouds over the KSC SLF weather observation site (KTTS), based on a comparative analysis of satellite imagery and the KTTS observations. The NOAA Radar Operations Center is processing the WSR-88D Layer Reflectivity Maximum products for the 45 case days. These will be used in a comparative analysis with the surface observations of anvil transparency from KTTS.

Information about upper atmosphere winds and cloud over Shuttle Transatlantic Abort Landing (TAL) sites is critical for making split-second decisions during the Shuttle launch phases. In the past, a Radio Automatic Theodolite System (RATS) was used to provide SMG with upper level winds, temperatures and humidity at TAL sites in Spain, Morocco, and Gambia. RATS became obsolete when the manufacturer announced cessation of sonde production. A replacement system, a Global Positioning System (GPS) based Sippican W9000, was selected, procured, integrated and tested with the help of the Eastern Range (ER). The initial system is now installed and operational. The ER owns, operates and maintains the system for NASA.

The KSC Weather Office funded development of a new lightning detection system capable of locating lightning strikes in 4D with an accuracy of <5 meters (a considerable improvement over the 250-300 meter accuracy of the current lightning location system.) Called SOLLO, it uses a sensor to detect the time of arrival of the electromagnetic pulse from a lightning strike, and then one elevated detector and three surface based detectors to measure the time of arrival of thunder from the lightning, to very accurately calculate the location of the lightning strike. SOLLO also calculates the amperage, rise time, and polarity of the

strike. During FY 2004, KSC is replacing/upgrading SOLLO components to enhance its capability to operate reliably in the corrosive KSC/ER environment. During the 2004 spring/summer lightning season, KSC will install SOLLO systems at the Shuttle Launch Complex, the ISS Building, and a new technology development and testing facility.

NASA OFFICE OF EARTH SCIENCES - RESEARCH PROGRAM

The supporting research activities are sponsored by the NASA Earth Science Enterprise (ESE). The ESE's mission is to understand and protect our home planet by using our view from space to study the Earth system, and improve prediction of Earth system change. The Enterprise pursues answers to the fundamental question: "How is Earth changing, and what are the consequences for life on Earth?" NASA's unique contributions to Earth system science include:

1. Creating the ability to study the Earth as an integrated physical and biological system. NASA is pioneering new remote sensing capabilities from a variety of vantage points. Global-scale changes require a global perspective, and local and regional changes can only be fully understood in their global context;

2. Addressing fundamental scientific questions with an 'end-to-end' approach that integrates Earth observation, interdisciplinary research, and Earth system modeling, providing comprehensive results to Earth science questions that inform policy and economic decisions;

3. Advancing remote sensing technology and computational modeling for scientific purposes, and facilitating the transition of mature observations and technologies to partner agencies that provide essential services using Earth science information;

4. Forging domestic and international partnerships to explore the com-

plex Earth system. NASA has the program management and system engineering expertise to help lead complex, multi-partner research endeavors as well as make unique contributions to those led by other nations and organizations.

With the power to observe Earth from space and to employ these observations in computational models of Earth system processes, NASA and its partners are gaining new insight into how the Earth system works. This understanding has provided confidence that we are on the verge of establishing predictive capabilities for the Earth system that will permit the assessment of the consequences of change for life on Earth. Over the next decade, NASA's ESE and its partners will enable prediction of:

1. Climate variability and change, and scientific assessment of the impacts of changes in global sea level and ocean circulations, regional temperature, precipitation and soil moisture;

2. Recovery of Earth's atmospheric ozone shield and assessment of the quality of the air we breathe;

3. Extended weather patterns, for early formation and the probable pathway of severe storms and hurricanes for planning evacuations and protecting life and property;

4. Seasonal flooding, droughts and water supply by region globally, and their impact on agriculture and fire hazards.

STRATEGY FOR ACHIEVING GOALS

SCIENCE

Earth is the only planet we know that sustains life. Life on Earth is critically dependent on the abundance of water in all three phases - liquid, vapor and ice. Carbon, existing in a variety of forms, is the very basis of life, and its greatest reservoir. In the atmosphere, carbon fully oxidized as carbon dioxide, fully reduced as methane, and in particulate form as black carbon soot produces the greenhouse effect making

Earth habitable. Earth's atmosphere and electromagnetic field protect the planet from harmful radiation while allowing useful radiation to reach the surface and sustain life. Earth exists within the Sun's zone of habitation, and with the moon, maintains the precise orbital inclination needed to produce our seasons.

These remarkable factors have contributed to Earth maintaining a temperature range conducive to the evolution of life for billions of years. The great circulation systems of the Earth - water, carbon and the nutrients - replenish what life needs and help regulate the climate system. Earth is a dynamic planet; the continents, atmosphere, oceans, ice and life ever changing, ever interacting in myriad ways. These complex and interconnected processes comprise the Earth system, which forms the basis of the scientific research and space observation that we refer to as Earth system science.

In Earth system science, researchers take a contextual approach to scientific inquiry - for instance, they explore extreme weather events in the context of changing climate. This leads to exploration and discovery of causes and effects in the environment. Earth system scientists have linked ocean temperatures and circulation to the moderate climate of northern Europe relative to its latitude, the annual changes of ozone concentration over Antarctica with the production of industrial refrigerants in the Northern Hemisphere, and the physics and chemistry of the atmosphere to air quality and fresh water availability.

Earth systems science has begun to understand and quantify the effects of "forcings" on the climate system produced by the Sun's solar variability and the atmosphere's increasing concentrations of carbon dioxide and aerosols. We have documented the dynamics of Earth's ozone layer and the effects of its depletion on exposure to UV radiation at the Earth's surface. We have

measured the Earth's radiation budget and its variations with unprecedented accuracy to assess its impacts on Earth's climate and weather. And we have measured the distribution of clouds and assess the crucial role they play in modulating short-term and long-term climate variations.

ESE research has also focussed on several important modes of natural climate variability that occur on decadal time scales. These include the North Atlantic Oscillation, the Pacific Decadal Oscillation, and the El Nino Southern Oscillation. The complex linkages between atmospheric fluxes and ocean heat transport/storage lead to adjustments in the basin-wide circulation of the oceans on timescales from years to decades. Atmospheric variability and/or response to changes in ocean surface temperature affect surface winds, deep water formation, and ocean surface temperature and stratification. Each of these coupled air-ocean oscillations have wide-ranging effects on short-term climate variability, and there is growing evidence that changes in one of these coupled ocean-atmosphere modes can impact the others.

NASA's Research Strategy for 2000-2010 describes NASA's approach to addressing the aforementioned science issues. Established are six scientific focus areas for these complex processes, each with a comprehensive roadmap which charts currently available products, knowledge steps, required capabilities and a ten-year outcome. The six focus areas comprise:

- 1) Weather;
- 2) Climate;
- 3) Atmospheric Composition;
- 4) Water and Energy Cycle;
- 5) Earth Surface and Interior; and
- 6) Carbon Cycle and Ecosystems.

These focus areas are interrelated, and must eventually be integrated to arrive at a fully interactive and realistic Earth system representation.

APPLICATIONS

NASA's objective for the ESE's Applications program is to expand and accelerate the realization of economic and societal benefits from Earth science, information and technology. This objective is accomplished by using a systems approach to facilitate the assimilation of Earth observations and predictions into the decision support tools used by partner organizations to provide essential services to society. These services include management of forest fires, coastal zones, agriculture, weather prediction and hazard mitigation, and aviation safety. In this way, NASA's long-term research programs yield near-term practical benefits to society. Thus, the Applications program enables the ESE to be citizen-centered, results-oriented, and market-driven.

The ESE's Applications program is engaged in twelve national applications with partner Federal agencies that can significantly benefit from NASA's observations and research results. These agencies include USDA, FEMA, FAA, EPA and others. For example, the Federal Aviation Administration, with the aviation industry, delivers the benefits of the National Airspace System to travelers, and NASA supports that system with atmospheric observations and predictions, and with synthetic vision technology. The twelve applications of national priority, which draw from research in the six science focus areas, include: Renewable Energy, Agricultural Efficiency, Carbon Management, Aviation, Homeland Security, Ecological Forecasting, Disaster Preparedness, Public Health, Coastal Management, Invasive Species, Water Management, and Air Quality.

TECHNOLOGY

NASA's Earth-observing satellites and sponsored research have led scien-

tists to view the Earth as a system - a dynamic set of interactions among continents, atmosphere, oceans, ice and life. This profound realization gave rise to the birth of the new interdisciplinary field of Earth system science. This way of studying the Earth is critical to understanding, for example, how global climate responds to the forces acting on it.

From the 1960s through the 1980s we developed the technology to view the Earth globally from space, focusing on individual components of the Earth system. This launched an era of rich scientific discovery, including the discovery of the processes behind Antarctic ozone, and the Earth's response to incoming solar radiation.

In the 1980s and 1990s we developed the interdisciplinary field of Earth system science, and began to survey the Earth system in its entirety, leading to the deployment of the Earth Observing System (EOS). During this period, scientists used space-based observations, coupled with suborbital and in situ observations, to uncover the mechanics behind the El Nino-La Nina cycle and begin modeling the climate system in a meaningful way. For the first time, scientists were able to measure the global distribution of atmospheric aerosols and related changes over seasons and years.

In the new century, we are completing the first phase of the EOS and securing the partnerships needed to achieve and sustain a long-term continuum of climate data. EOS exploratory missions such as the Tropical Rainfall Measurement Mission (TRMM) satellite have uncovered a wealth of new information about precipitation processes and have led to the most accurate mapping of rainfall across the global tropics and subtropics. Fully-



vested EOS satellites such as Aqua are providing high resolution, global soundings to better characterize atmospheric circulation, temperature profiles, water content, and greenhouse gasses. Planned missions such as Aura will take critical measurements addressing air quality, ozone, and glob-

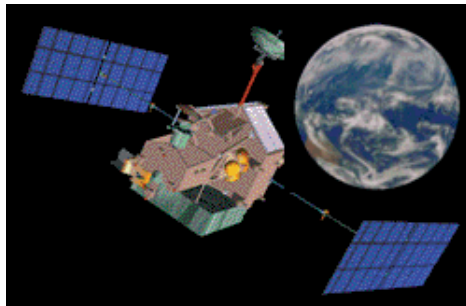


Figure 3-NASA-1. TRMM Satellite.

al climate. An example of an EOS Next Generation mission, the Global Precipitation Mission, will extend and enhance the TRMM record of precipitation measurements by expanding coverage to high latitudes and providing overflights of most locations every three hours.

NASA's EOS also serves as the technology source for the next generation of Polar-Orbiting Operational Environmental Satellites (POES). NOAA, DOD and NASA are proceeding with the development of POES in a joint civilian/military project called NPOESS. Bridging EOS and NPOESS is the NPOESS Preparatory Project (NPP or "Bridge Mission"), a multi-instrument satellite that will extend climate change measurements begun by EOS Terra and Aqua while demonstrating new technologies for NPOESS. NASA and NOAA will also continue to plan the next generation of Geostationary Operational Environmental Satellites (GOES). NASA plans to fly an advanced atmospheric sounder to a geostationary orbit where it will make continuous measurements of weather-related phenomena to improve "nowcasting" of extreme weather events and measurement of important atmospheric gasses. Today's

satellites have enable weather forecasts to be extended from three days to five. The next generation of satellites will enable the extension of forecasts to seven days within this decade.

In collaboration with our research partners, we will pursue an understanding of the Earth system through the integration of satellite, suborbital and surface measurements in conjunction with models that simulate links and feedback between Earth system processes. In the years ahead, Earth-orbiting satellites will evolve into constellations of smart satellites that can be reconfigured based on the changing needs of science and technology. From there we envision an intelligent and integrated observation network composed of sensors, deployed in vantage points from the subsurface to deep space. This "sensorweb" will provide on-demand data and analysis to a wide range of end users in a timely and cost-effective manner.

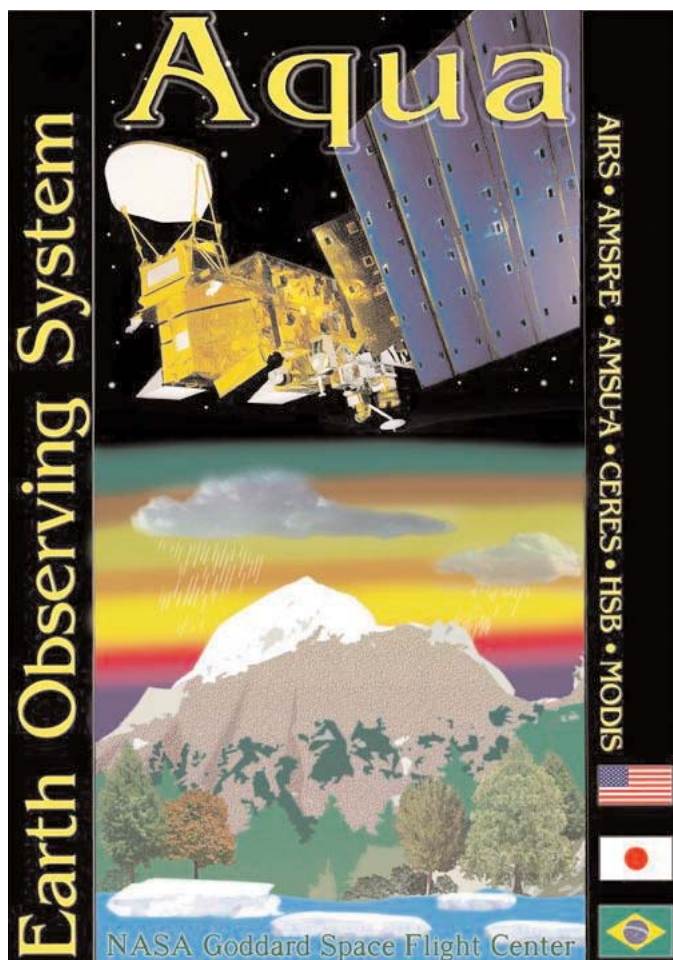
PARTNERSHIPS

NASA's ESE has many partners in the advancement of Earth system science and its application to societal concerns. NASA is a major partner in the U.S. Global Change Research Program (USGCRP), an interagency effort to understand the processes and patterns of global change. The USGCRP coordinates research among ten U.S. government agencies. NASA collaborates with the USGCRP on a range of land surface, solid Earth and hydrological research projects. As described in the previous section, NASA has extensive

collaboration with the NOAA on weather and climate-related programs. NASA partners with other Federal agencies under the auspices of the U.S. Climate Change Science and Technology Programs, to provide a sound scientific basis for the policy decisions and to mitigate or adapt to the impacts of climate change. In addition, NASA participates in the international programs of World Climate Research, the International Geosphere/Biosphere, and the World Meteorological Organization.

In the arena of private industry, the NASA ESE partners to develop technologies of the future, and specifically the commercial remote sensing industry to enhance the scientific utility of commercial imagery.

International cooperation is an essential element in the Earth science program. Earth science addresses global issues and requires international



involvement in its implementation and application. Most of the ESE satellite missions have international participation, ranging from simple data sharing agreements to joint missions involving provision of instruments, spacecraft, and launch services. The NASA ESE has forged 290 agreements with 60 countries. In addition, nearly 2000 research and technology grants and contracts with universities and research laboratories nationwide help extend NASA ESE's efforts in basic research, benchmarking applications of new scientific results, and creating innovative technologies.

SIDEBAR: NASA Helps to Unravel Secrets of Hurricanes

In recent years, NASA has made strides in investigating the structure and behavior of tropical cyclones. The new insights into the nature of these deadly storms have come from a multi-pronged approach, fusing Earth Observing System (EOS) datasets with a comprehensive series of aircraft missions called the Convection and Moisture Experiment (CAMEX), and numerical modeling studies.

Satellite remote sensors such as the Tropical Rainfall Measuring Mission (TRMM) Precipitation Radar have collected rich datasets on hundreds of tropical cyclones around the globe. The TRMM radar is the only instrument capable of elucidating the vertical rain structure of these storms over the oceans. Precipitation Radar data, when combined with the TRMM Microwave Imager, have been used to characterize asymmetries in tropical cyclone rainfall, and identify exceptionally vigorous convective clouds which often presage intensification. The QuickSCAT instrument provides detailed sea surface winds, which

assists forecasters in the early identification of vortices contained in tropical waves - the "seedlings" that occasionally intensify into tropical storms. In addition, the Advanced Microwave Sounding Radiometer (AMS-R-E) flying on NASA's Aura satellite provides detailed observations of ocean surface

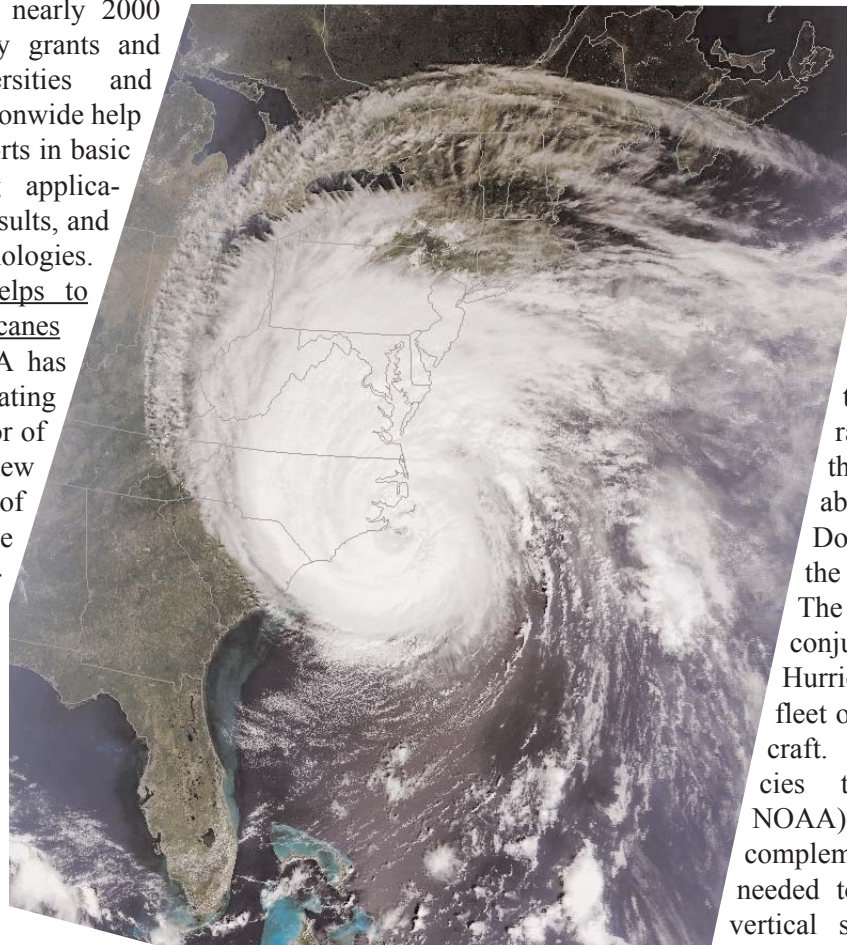


Figure 3-NASA-2. EOS TERRA satellite captures the extent of Hurricane Isabel's impact on the East Coast on September 18, 2004

temperature. AMSR-E is critical for delineating the 26C ocean surface temperature threshold necessary for tropical cyclones to intensify. NASA's comprehensive suite of remote sensors is allowing researchers to piece together all the components of the hurricane "engine" - the vortex winds, rainfall, ocean energy source and thermal structure inside the eye (Figure 3-NASA-2).

NASA's intensive view of tropical storms from space is augmented by the CAMEX series of airborne investiga-

tions into hurricanes over the Atlantic, Caribbean and Gulf of Mexico. During both of these experiments, conducted in 1998 and 2001 (and a third being planned for the Eastern Pacific in 2005), NASA operated sophisticated "flying laboratories" in the upper atmosphere. The NASA DC-8 and ER-2 were equipped with an array of remote sensors (lidars, radars and radiometers) and in-situ probes designed to measure every facet of the hurricane environment. These properties include the cloud microphysical processes that generate ice and rain, electrical fields, the three dimensional variability of water vapor, and Doppler air motions within the eyewall and rainbands. The missions were flown in conjunction with the NOAA Hurricane Research Division fleet of lower atmospheric aircraft. Teaming the two agencies together (NASA and NOAA) provided the perfect complement of airborne assets needed to investigate the entire vertical structure of hurricanes,

from the ocean surface upward through 70,000 feet. Ten different storms in all stages of the lifecycle (genesis, maturity and decay) were investigated during CAMEX and the exciting scientific results will be published in an upcoming special issue of the Journal of the Atmospheric Sciences.

Comprehensive datasets collected from space and in the field have provided many intriguing insights into the processes that govern hurricane growth and evolution. Numerical modeling investigations take the analyzes a step further by assimilating diverse observational datasets into a theoretical framework for performing experi-

ments. Assimilation of CAMEX water vapor measurements, for instance, into the Florida State University (FSU) superensemble model demonstrates a new ability to improve both hurricane track and intensity forecasts. High resolution simulations of Hurricanes Bonnie and Erin using the Penn State MM5 model using CAMEX data have revealed new insights into processes controlling the intensity of eyewall convection, and the role this convection plays in the water and energy budgets of these storms.

AVIATION SAFETY PROGRAM

NASA's Aviation Safety Program is aggressively pursuing several areas that will provide weather information, avoidance, and mitigation technologies, and education and training aids. The following elements are included:

- Aviation Weather Information (AWIN) develops technologies that provide high fidelity, timely, and intuitive information to pilots to enable the

detection and avoidance of atmospheric hazards (Figure 3-NASA-3).

- Weather Information Communications (WINCOM) develops advanced communication technologies and architectural concepts to provide weather information, avoidance, and mitigation technologies, icing design and analysis tools, icing education and training aids, and accurate and timely weather information to the cockpit for both national and international flight.

- Turbulence Prediction and Warning System (TPAWS) develops airborne turbulence warning systems and associated crew procedures to mitigate upsets from all types of turbulence encounters, including clear air turbulence (CAT).

- Aircraft Icing (AI) addresses critical technology gaps in ice prediction, detection, avoidance, and mitigation capability to reduce safety hazards, aviation system throughput impacts, cost of air travel, and design cycle time.

The project will:

- develop validated analytical and experimental tools for design and certification/qualification of aircraft systems in icing;

- develop improved predictions, forecasting, and resolution of in-flight icing conditions;

- better understand the effects of ice contamination on aircraft performance, stability and control, and handling qualities;

- develop ice protection systems, including ice sensing, prevention, and removal;

- develop methods for avoiding in-flight icing hazardous conditions by using remote sensing technologies and flight deck information management; and

- develop icing related educational materials and training aids for pilots, airline operators, and dispatchers.

Synthetic Vision Systems (SVS). NASA is developing "synthetic" (electronically enhanced) vision for the pilot (Figure 3-NASA-4). It combines a very detailed worldwide terrain map (obtained from Space Shuttle mapping



Figure 3-NASA-3. NASA and aviation industry vendors have developed an initial Aviation Weather Information (AWIN) system which is graphical and intuitive for ease of use. Designed to replace bulky, text printouts, AWIN will put graphical weather information in the cockpit.

missions), precise GPS navigation data, and integrity-monitoring sensors to provide a 3-dimensional, realistic view of the world through a cockpit head-up-display (HUD) or instrument panel-mounted display. The pilot will look through the HUD as he or she looks out the window. This see-through HUD will make the world look like a bright sunny day even when the airplane is approaching a fogged-in airport at midnight—one that would be shut down under today's operating rules. NASA believes that improving the pilot's situational awareness will largely eliminate controlled-flight-into-terrain (CFIT) and runway incursion accidents. NASA is also evaluating the use of modified weather radar and FLIR for runway object detection.

Limited visibility is the single most critical factor affecting both the safety and capacity of worldwide aviation operations. In commercial aviation, over 30 percent of all fatal accidents worldwide, and the leading cause of total fatalities, are categorized as controlled flight into terrain -- accidents in which a functioning aircraft impacts terrain or obstacles that the flight crew could not see. In addition, the largest general aviation accident category is 'Continued Flight into Instrument Meteorological Conditions', in which low-experience pilots continue to fly into deteriorating weather and visibility conditions and either collide with unexpected terrain or lose control of the vehicle because of the lack of familiar external cues. The goal of the synthet-

ic vision work is to achieve VMC capability in IMC (to Category IIIB).

General Aviation. NASA's Small Aircraft Transportation System (SATS) research program will demonstrate technology to safely guide a small aircraft in near all-weather conditions to virtually any small airport in non-radar, non-towered airspace (Figure 3-NASA-5). The elements are:

- Higher Volume Operation at Non-Towered/Non-Radar Airports will enable simultaneous operations by multiple aircraft in non-radar airspace at and around small non-towered airports in near all weather conditions through the use of vehicle-to-vehicle collaborative sequencing and self-separation algorithms and automated flight path management systems.

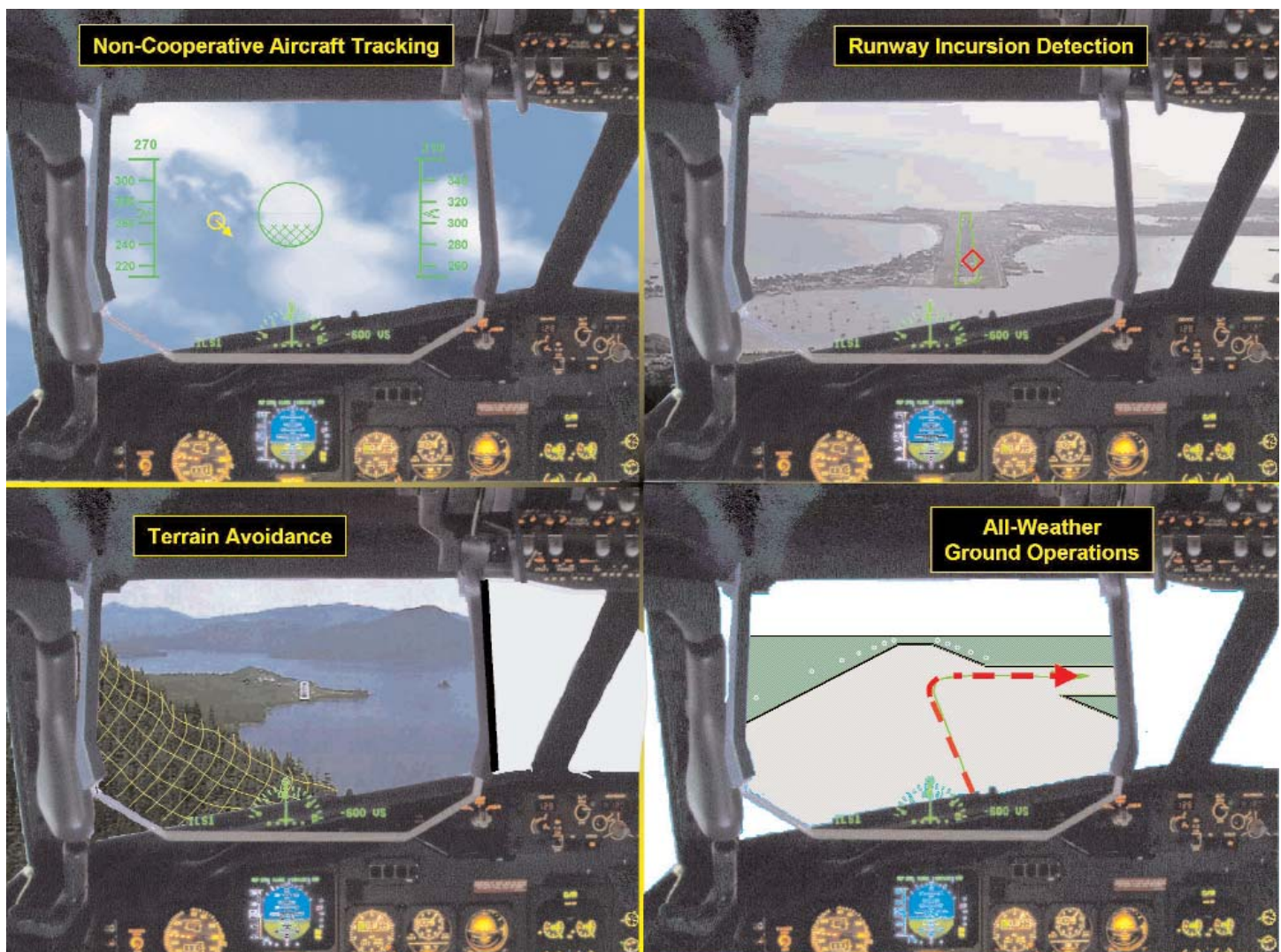


Figure 3-NASA-4. Four examples of synthetic vision systems which enhance a pilot's vision through heads-up displays.

- Lower Landing Minimums at Minimally Equipped Landing Facilities will provide precision approach and landing guidance, through the use of graphical flight path guidance and artificial vision, to any touchdown zone at any landing facility while avoiding land acquisition and approach lighting costs, as well as ground-based precision guidance systems, such as ILS.

- Increase Single-pilot crew Safety and Mission Reliability will increase single-pilot safety, precision, and mission completion through the use of human-centered automation, intuitive and easy to follow flight path guidance superimposed on a depiction of the outside world, software enabled flight controls, and onboard flight planning/management systems.

- En Route Procedures and Systems for Integrated Fleet Operations will provide an analytical assessment of the impact of automated flight path management systems designed to facilitate operations at non-towered airports and in non-radar airspace on the integration of SATS equipped aircraft into the higher en route air traffic flows and controlled terminal airspace.

GA Cockpit Display of Weather Information

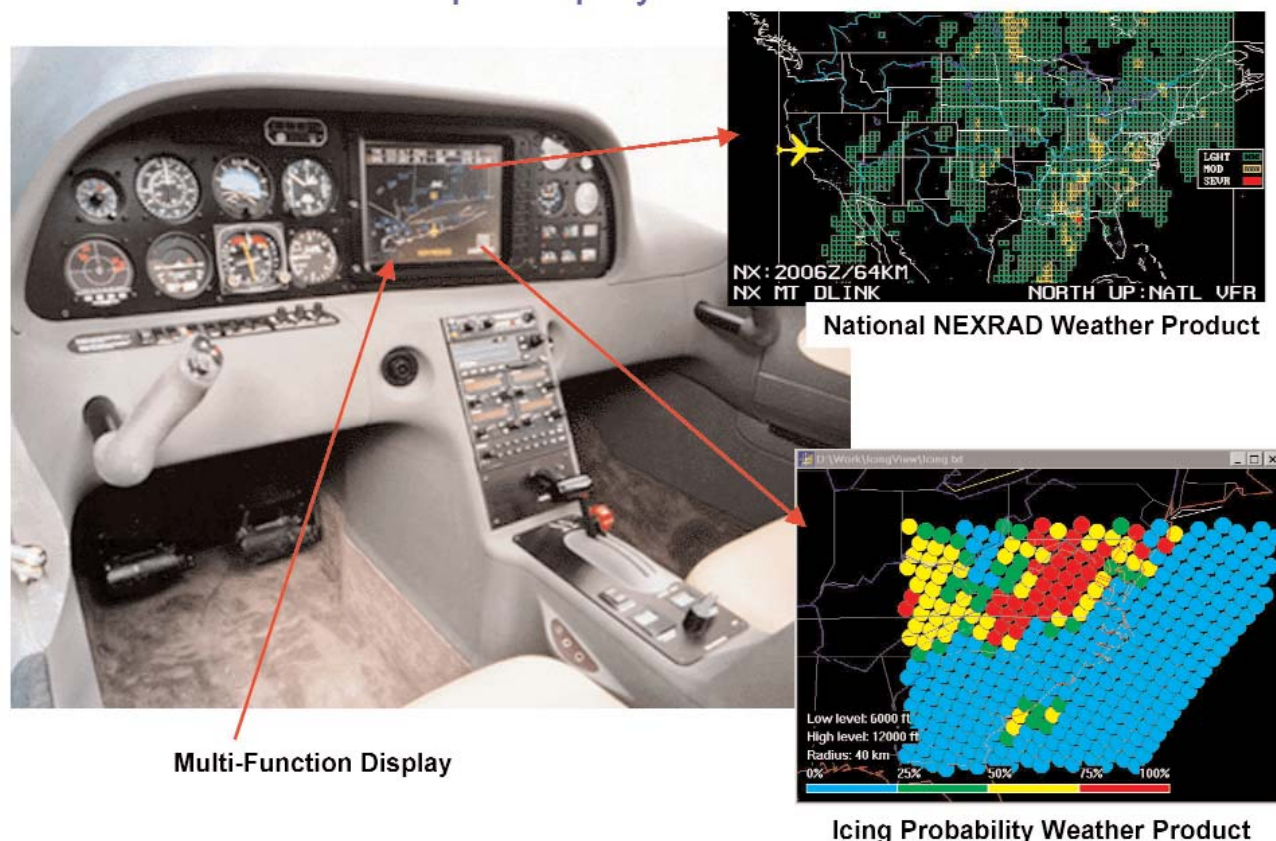


Figure 3-NASA-5. General Aviation cockpit display of weather information.

